Scattered thoughts on industrial energy assessments (With a focus on pumping systems)

For: BPA Utility Energy Efficiency Workshop

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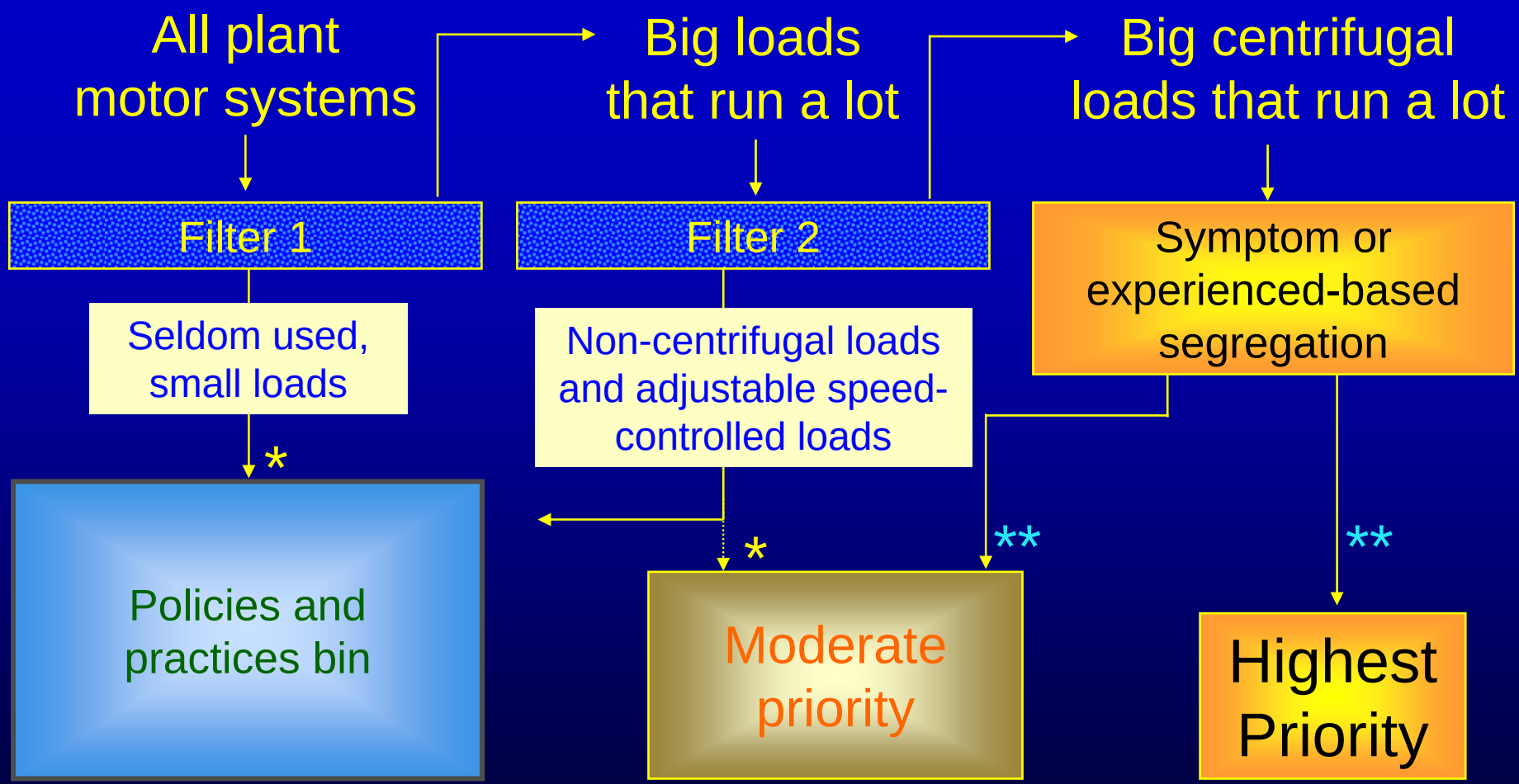
May 18, 2007

Subjects sequence

- Prescreening – applying the Pareto Principle
- Non-energy considerations
- Partnering with plant folks
- Measuring – the unappreciated science and art
- Analysis - examples

Prescreening to narrow the field of focus - i.e., to select the VITAL FEW for further review



* Productivity/reliability-critical systems sent to higher priority levels

** Policies & practices also apply to moderate & highest priority applications

Symptoms in pumping systems that indicate potential energy opportunity (and more)

Look for:

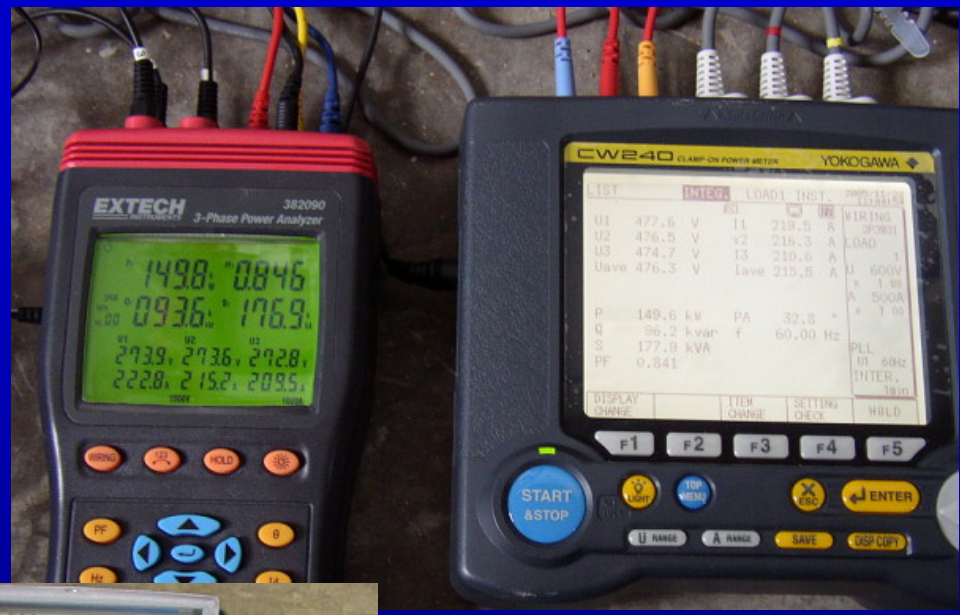
- Throttle valve-controlled systems
- Bypass (recirculation) line normally open
- Multiple parallel pump system with same number of pumps always operating
- Constant pump operation in a batch environment or frequent cycle batch operation in a continuous process
- Cavitation noise (at pump or elsewhere in the system)
- High system maintenance

Partnering in multiple domains – you gotta love it

Measuring – it ain't always easy

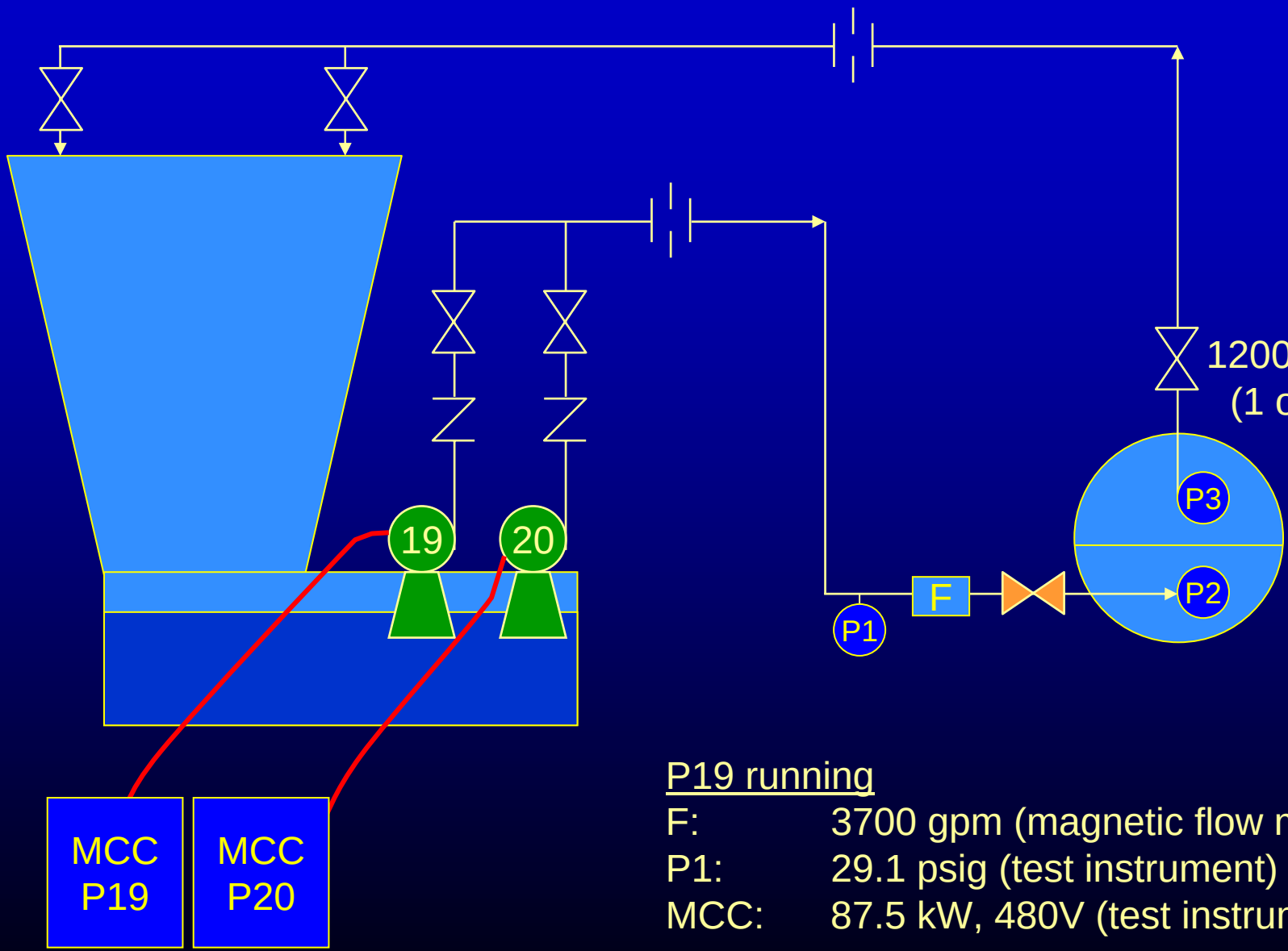
It ain't always clean

And it definitely ain't cheap (well, maybe on E-bay)



But it is almost always the smart thing to do
in serious industrial settings

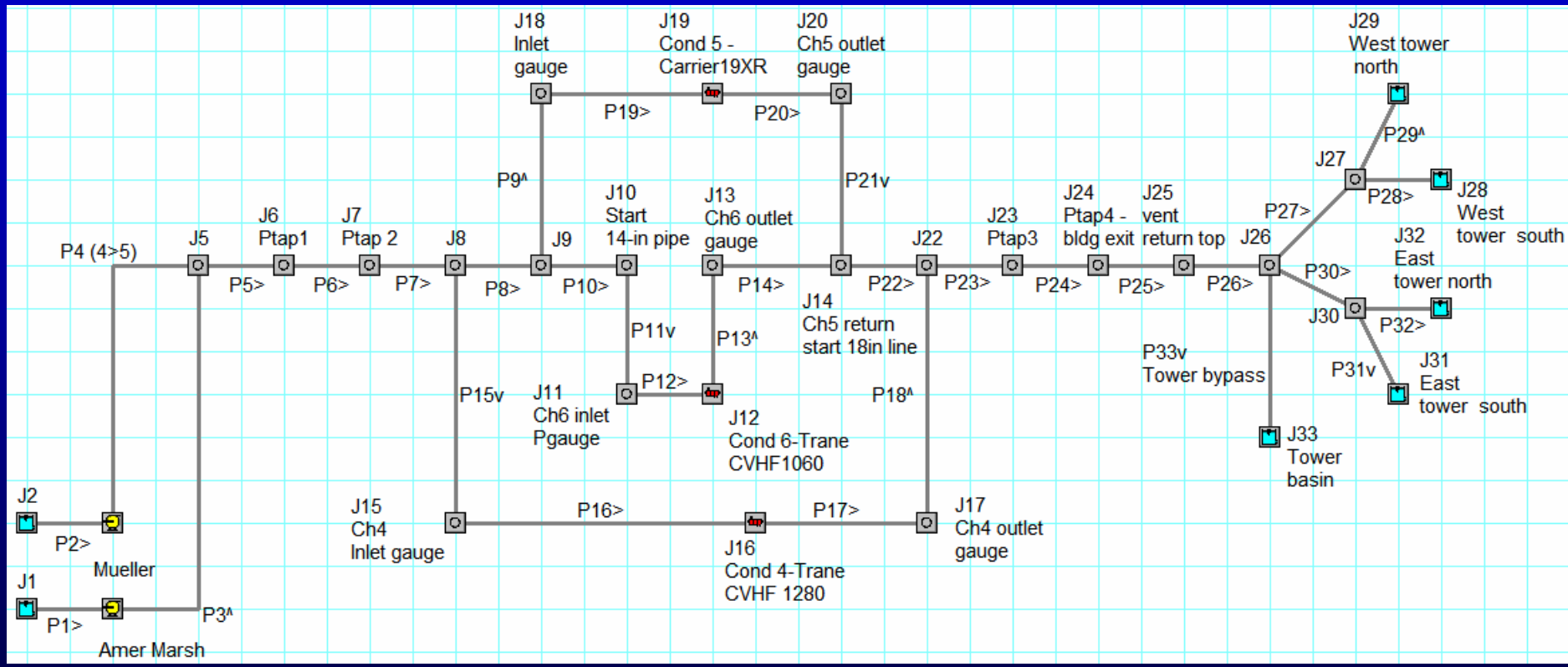
A simplified flow diagram for a system that we'll use as a talking point



P19 running

F:	3700 gpm (magnetic flow meter)
P1:	29.1 psig (test instrument)
MCC:	87.5 kW, 480V (test instrument)

A hydraulic model for this system



Note: the time required to assemble the model, including getting manufacturer performance data for valves, heat exchangers, and pumps, as well as just tabulating the line sizes and lengths, numbers and types of fittings, etc., was approximately 2 person-days.

Model vs. measured comparisons: there were some devils in the details

Parameter	Model	Actual	Actual/Model
P19 flow rate (gpm)	3683	3700	1.00
Pump head (ft)	54.1	73.1	1.35
Shaft power (hp)	80.8	109.3	1.35
Condenser dP (psid)	5.43	14.3	2.64

Measurement-based observations:

Pump data provided by the supplier was off; actual curve was beyond that provided. Pump was also operating at a higher than rated speed.

The condenser appears to have significant blockage on the inlet side; additional measurements showed that the dP on the second pass of the U-type condenser was normal.

The close matching of predicted and actual flow was basically coincidental

Quantifying the opportunity magnitude through measurement and analysis

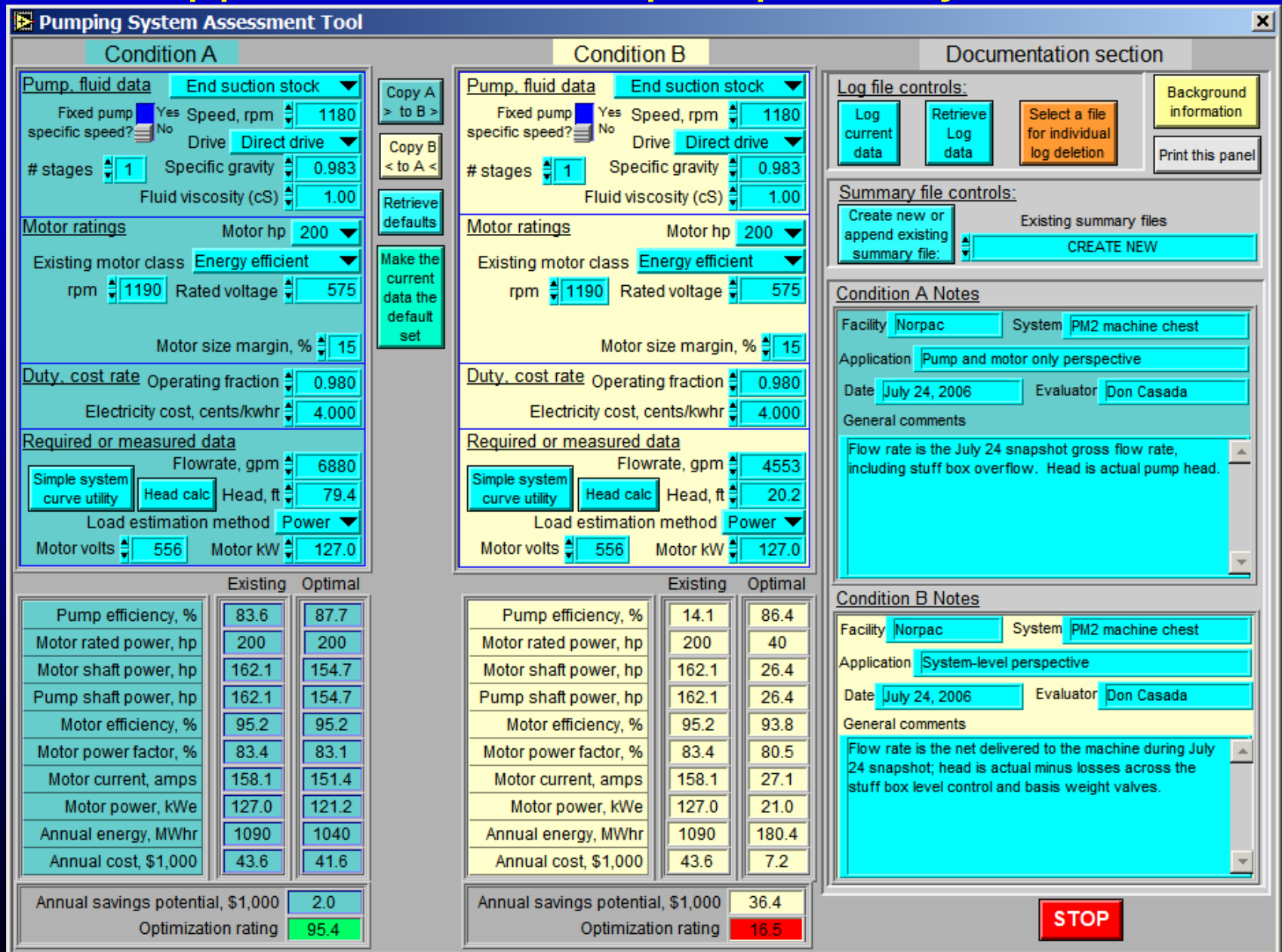
- Methods vary from snapshot-based, using tools such as the DOE's PSAT and valve energy loss software programs to more detailed engineering analyses
- Pay attention to details, but keep focus at the system level

Throttling and bypassing in a single application: machine chest to stuff box pumping

Logging machine chest pump pressures

Logging power data, using BPA-supplied equipment

PSAT evaluation of Norpac machine chest to stuff box application – at the pump and systems levels



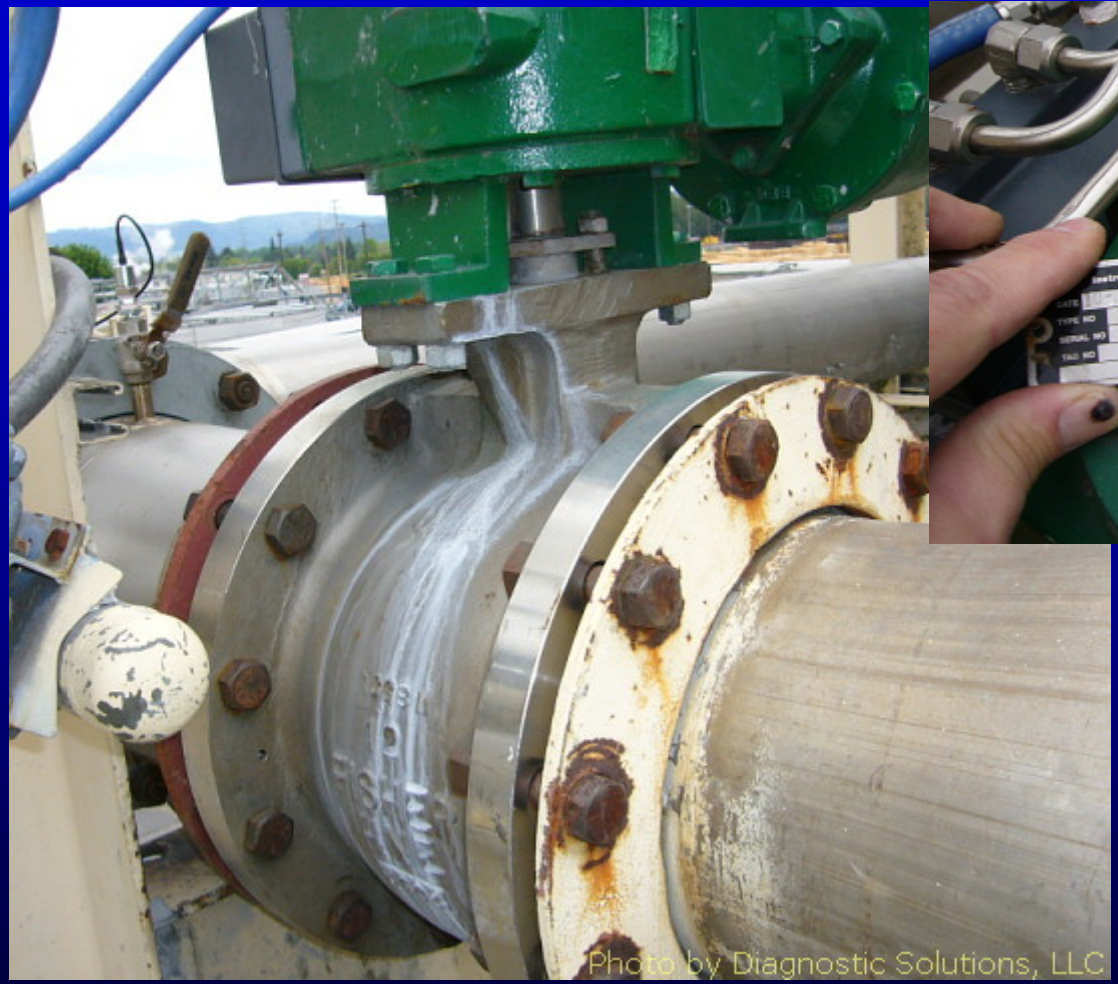
	Existing	Optimal
Pump efficiency, %	83.6	87.7
Motor rated power, hp	200	200
Motor shaft power, hp	162.1	154.7
Pump shaft power, hp	162.1	154.7
Motor efficiency, %	95.2	95.2
Motor power factor, %	83.4	83.1
Motor current, amps	158.1	151.4
Motor power, kWe	127.0	121.2
Annual energy, MWhr	1090	1040
Annual cost, $1,000	43.6	41.6

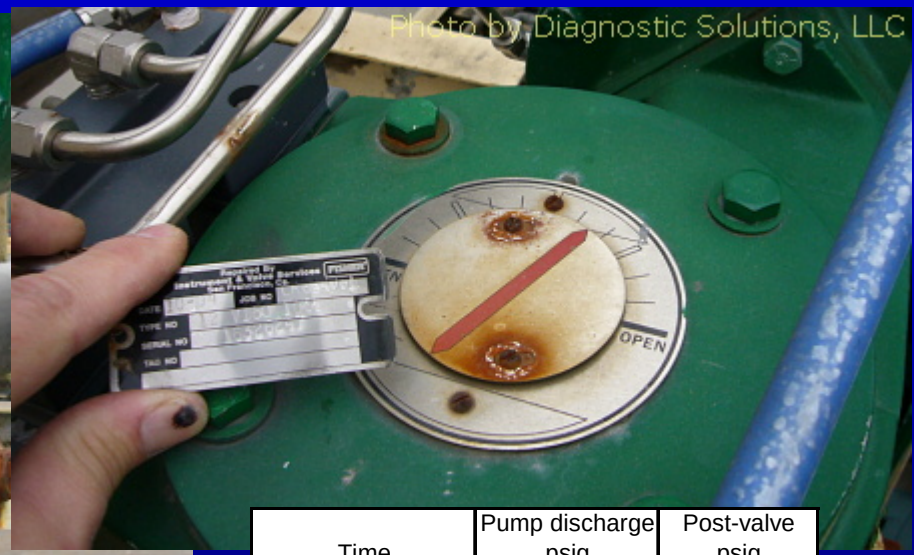
Annual savings potential, $1,000: 2.0
Optimization rating: 95.4

	Existing	Optimal
Pump efficiency, %	14.1	86.4
Motor rated power, hp	200	40
Motor shaft power, hp	162.1	26.4
Pump shaft power, hp	162.1	26.4
Motor efficiency, %	95.2	93.8
Motor power factor, %	83.4	80.5
Motor current, amps	158.1	27.1
Motor power, kWe	127.0	21.0
Annual energy, MWhr	1090	180.4
Annual cost, $1,000	43.6	7.2

Annual savings potential, $1,000: 36.4
Optimization rating: 16.5

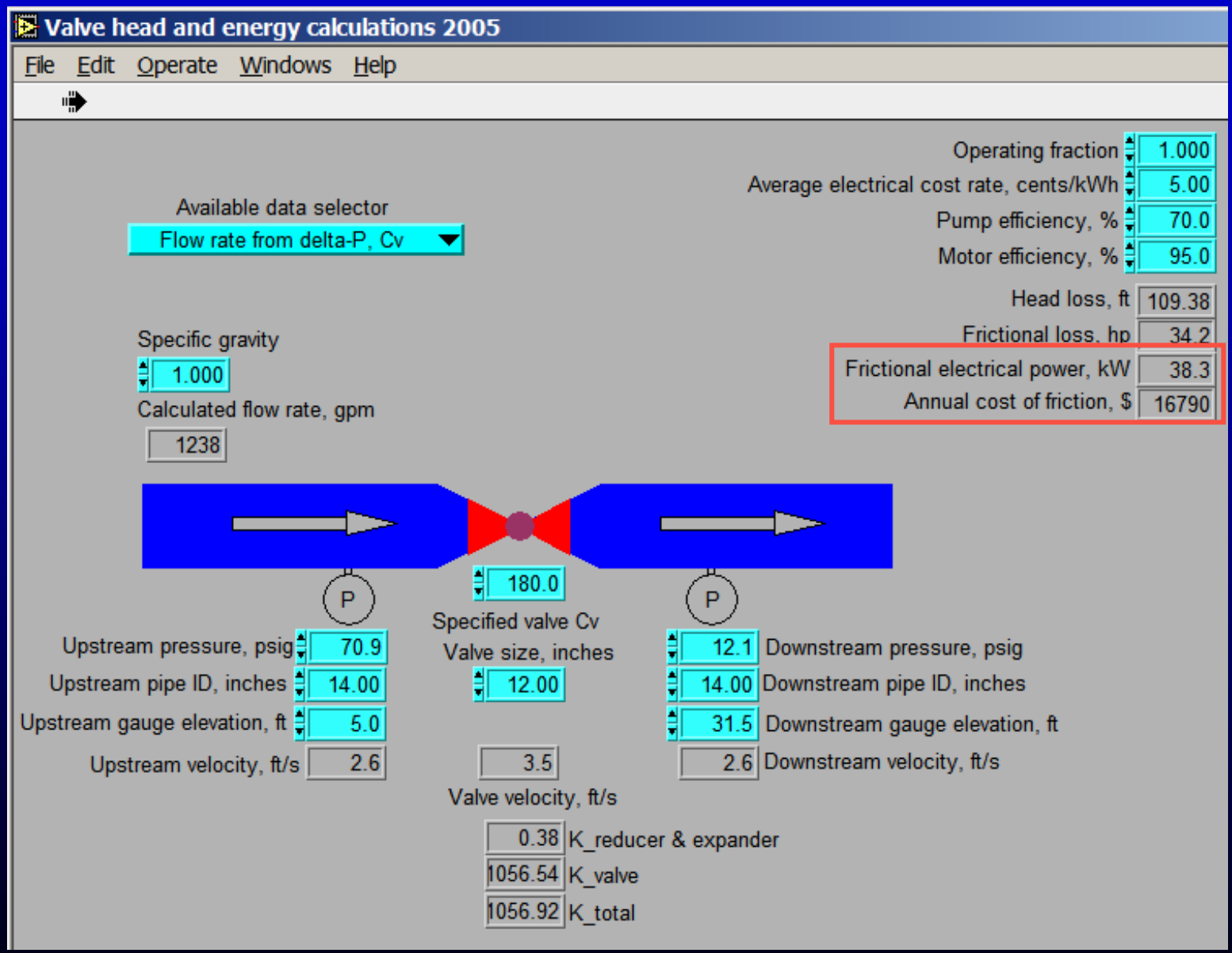
Collecting pressure and valve information to use with the valve tool included with PSAT



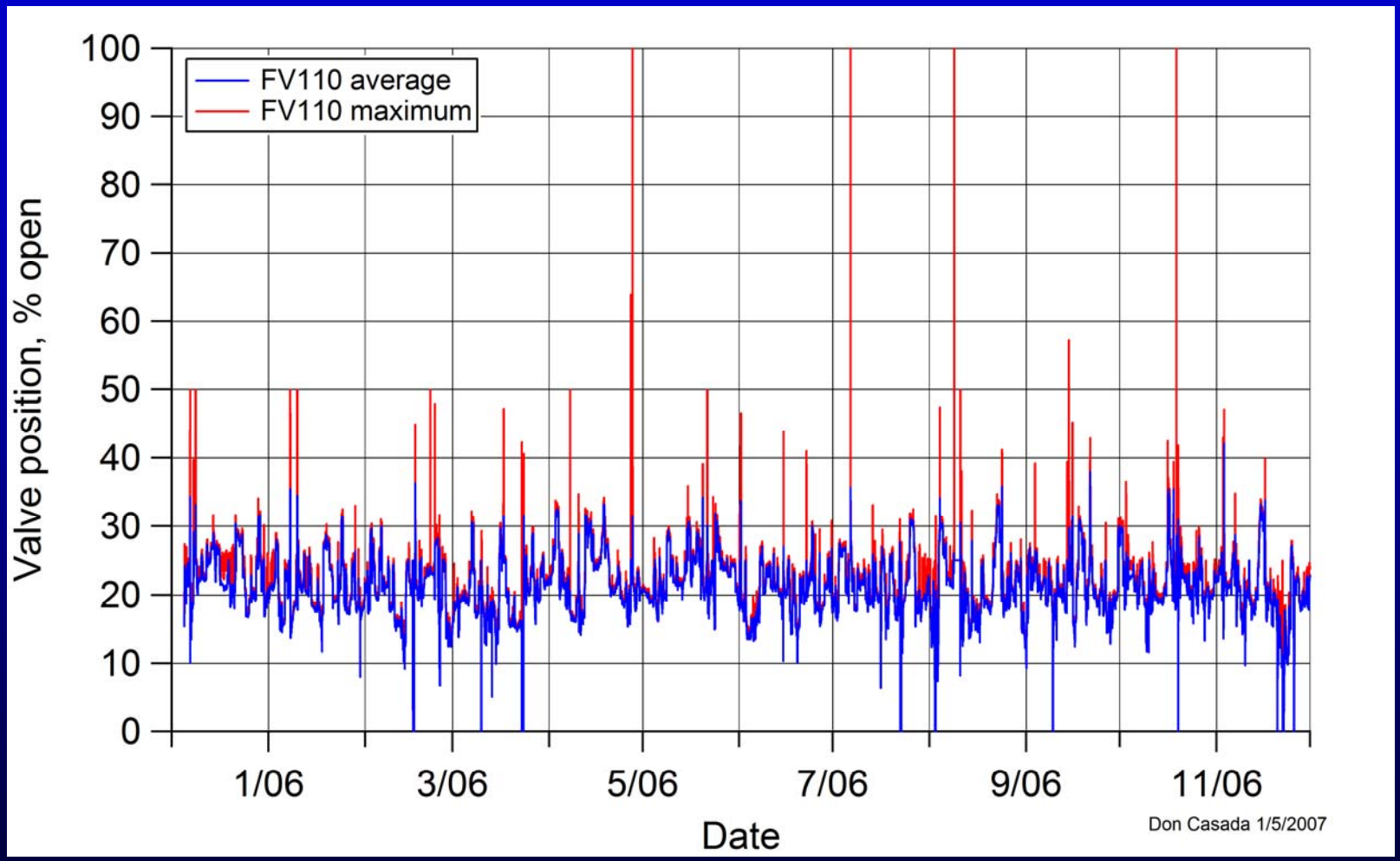


Time	Pump discharge psig	Post-valve psig
5/16 11:00:00	71.60	11.73
5/16 11:00:20	71.60	11.61
5/16 11:00:40	71.30	11.68
5/16 11:01:00	69.80	10.60
5/16 11:01:20	71.50	12.24
5/16 11:01:40	72.10	12.67
5/16 11:02:00	72.20	12.52
5/16 11:02:20	71.60	11.82
5/16 11:02:40	71.50	12.57
5/16 11:03:00	**70.90**	**12.11**
5/16 11:03:20	71.00	11.91
5/16 11:03:40	71.70	12.77
5/16 11:04:00	71.90	12.55
5/16 11:04:20	72.00	12.85
5/16 11:04:40	71.20	11.89
5/16 11:05:00	70.00	11.50
5/16 11:05:20	70.00	11.15
5/16 11:05:40	70.80	12.05
5/16 11:06:00	71.30	12.40
5/16 11:06:20	71.70	12.86
5/16 11:06:40	71.50	12.70
5/16 11:07:00	70.20	11.21

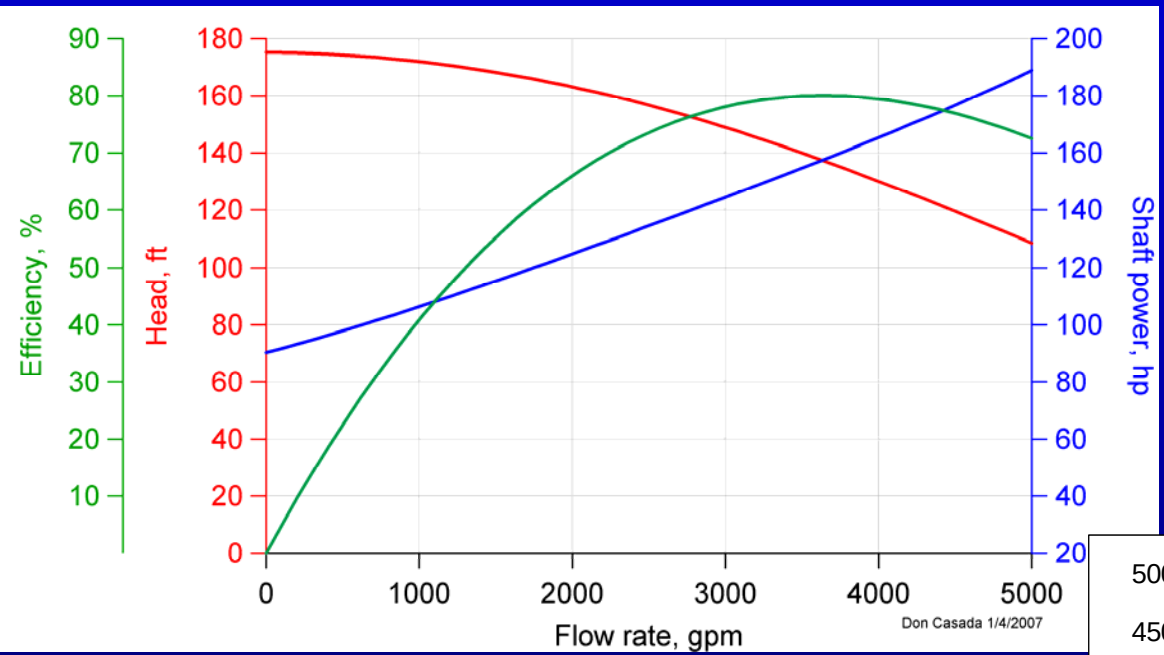
The electrical power related to valve throttling, and the associated annual energy cost are calculated

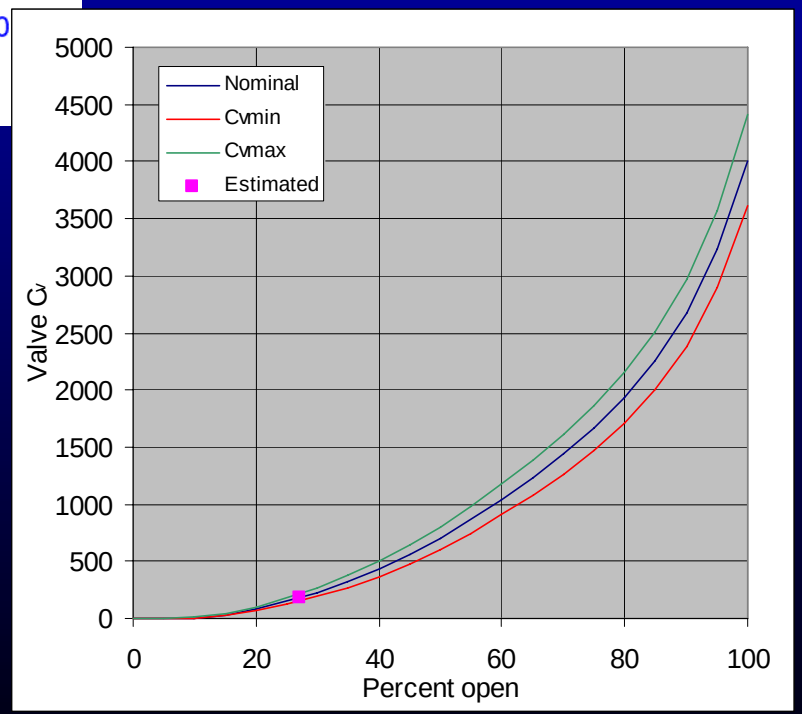


The same techniques can be applied to long-term, varying condition data



Equipment performance curves are often used in conjunction with field data





Historical data supports detailed estimates of losses

DWG #	15-N-5001B	15-N-5001B												
	TMP and DI to blend flow	TMP and DI to blend FCV												
	gpm	% open												
time	15-FIC-0110	15-FIC-0110.COI	Nominal Cv	Max Cv	Nominal dP	Nominal valve whp	Max Cv whp	Pump bhp	Pump head (Q)	Pump eff	Pump whp, no recirc	Motor kW	Nominal valve kW	Max Cv kW
12/5/05 1:00	504.8	15.4	57.8	69.6	76.2	22.4	15.48	98.2	174.4	22.7	22.2	77.9	78.6	54.2
12/5/05 2:00	605.6	17.2	68.7	82.2	77.8	27.5	19.18	99.9	174.1	26.7	26.6	79.2	81.8	57.1
12/5/05 3:00	874.2	21.9	100.5	118.9	75.6	38.5	27.56	104.4	172.9	36.6	38.2	82.9	83.7	59.8
12/5/05 4:00	1012.9	24.3	117.6	138.4	74.2	43.8	31.63	106.8	172.1	41.2	44.0	84.8	84.4	60.9
12/5/05 5:00	826.6	20.9	93.5	110.9	78.1	37.7	26.82	103.6	173.1	34.9	36.1	82.2	85.7	61.0
12/5/05 6:00	766.8	19.9	86.7	103.0	78.2	35.0	24.78	102.6	173.4	32.7	33.6	81.4	84.8	60.1
12/5/05 7:00	747.3	19.6	84.7	100.7	77.9	33.9	24.01	102.3	173.5	32.0	32.7	81.1	84.1	59.5
12/5/05 8:00	766.3	19.9	86.7	103.0	78.1	34.9	24.74	102.6	173.4	32.7	33.6	81.4	84.7	60.0
12/5/05 9:00	740.9	19.4	83.4	99.2	79.0	34.1	24.11	102.1	173.5	31.8	32.5	81.1	85.2	60.2
12/5/05 10:00	738.3	19.4	83.4	99.2	78.4	33.8	23.87	102.1	173.6	31.7	32.4	81.0	84.6	59.8
12/5/05 11:00	744.1	19.5	84.0	99.9	78.4	34.0	24.06	102.2	173.5	31.9	32.6	81.1	84.7	59.8
12/5/05 12:00	749.4	19.6	84.7	100.7	78.3	34.2	24.21	102.3	173.5	32.1	32.8	81.2	84.6	59.8
12/5/05 13:00	744.6	19.6	84.7	100.7	77.3	33.6	23.74	102.2	173.5	31.9	32.6	81.1	83.5	59.0
12/5/05 14:00	732.8	19.3	82.7	98.4	78.5	33.6	23.70	102.0	173.6	31.5	32.1	81.0	84.6	59.7
12/5/05 15:00	727.7	19.2	82.0	97.7	78.7	33.4	23.57	101.9	173.6	31.3	31.9	80.9	84.7	59.8
12/5/05 16:00	696.4	18.7	78.1	93.2	79.4	32.3	22.70	101.4	173.7	30.1	30.6	80.5	85.0	59.8
12/5/05 17:00	765.8	20.0	86.7	103.0	78.0	34.8	24.68	102.6	173.4	32.7	33.5	81.4	84.6	59.9
12/5/05 18:00	1012.3	23.8	113.8	134.1	79.1	46.7	33.67	106.8	172.1	41.2	44.0	84.8	90.1	64.9
12/5/05 19:00	949.8	22.8	107.1	126.4	78.7	43.6	31.29	105.7	172.5	39.1	41.4	83.9	88.4	63.5
12/5/05 20:00	933.3	22.5	104.9	123.9	79.2	43.1	30.90	105.4	172.6	38.6	40.7	83.7	88.7	63.6
12/5/05 21:00	939.6	22.6	104.9	123.9	80.3	44.0	31.53	105.5	172.5	38.8	40.9	83.8	90.0	64.5
12/5/05 22:00	991.7	23.5	111.5	131.5	79.1	45.7	32.91	106.5	172.2	40.5	43.1	84.5	89.6	64.5
12/5/05 23:00	1015.9	23.9	115.3	135.8	77.6	46.0	33.16	106.9	172.1	41.3	44.1	84.8	88.4	63.7
12/6/05 0:00	1008.6	23.8	113.8	134.1	78.6	46.2	33.30	106.7	172.1	41.1	43.8	84.7	89.3	64.3
12/6/05 1:00	1020.4	24.0	115.3	135.8	78.3	46.6	33.60	107.0	172.1	41.5	44.3	84.9	89.2	64.3
12/6/05 2:00	1038.1	24.3	118.4	139.3	76.9	46.6	33.63	107.3	171.9	42.0	45.1	85.1	88.0	63.5
12/6/05 3:00	1064.7	24.7	121.5	142.9	76.8	47.7	34.49	107.7	171.8	42.9	46.2	85.5	88.3	63.8
12/6/05 4:00	1061.1	24.7	120.7	142.0	77.3	47.8	34.58	107.7	171.8	42.8	46.0	85.4	88.8	64.2
12/6/05 5:00	979.3	23.4	110.8	130.6	78.2	44.6	32.11	106.2	172.3	40.1	42.6	84.3	88.3	63.5
12/6/05 6:00	865.5	21.3	96.3	114.1	80.8	40.8	29.08	104.3	172.9	36.2	37.8	82.8	89.3	63.7
12/6/05 7:00	858.0	21.2	95.6	113.2	80.6	40.3	28.73	104.1	173.0	36.0	37.5	82.7	88.9	63.4
12/6/05 8:00	893.7	21.8	99.1	117.3	81.3	42.4	30.27	104.8	172.8	37.2	39.0	83.1	90.4	64.5

Observation from many miles traveled on the industrial circuit: BPA's industrial energy program is – BY FAR – the best in the country; take advantage of it!